

WG1: Neutrino Oscillations Plans and Questions

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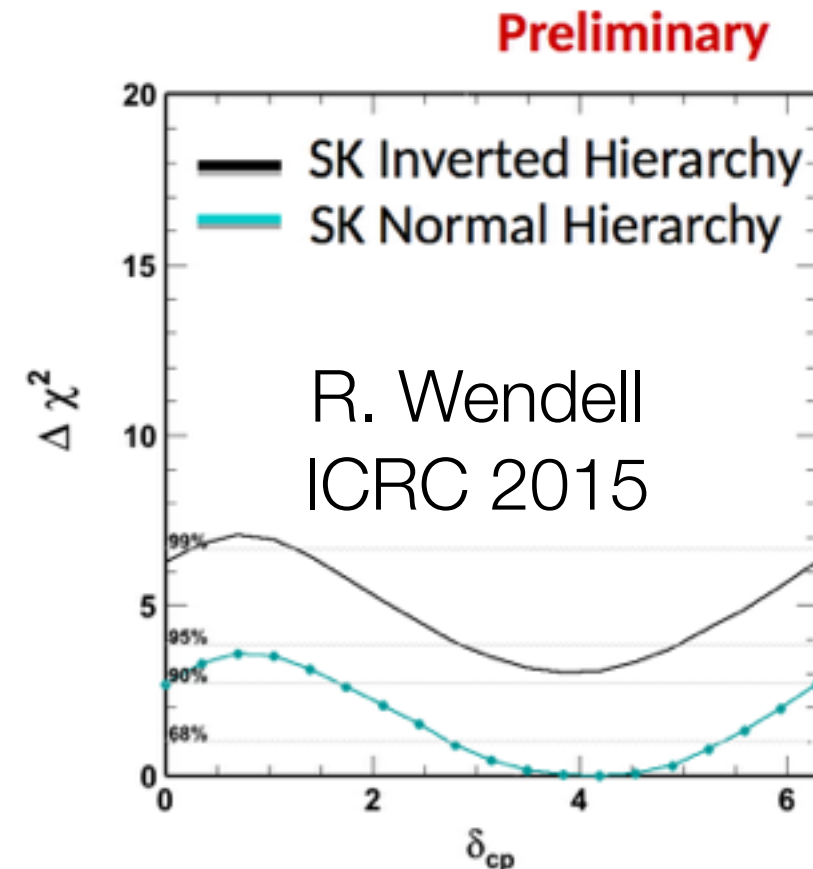
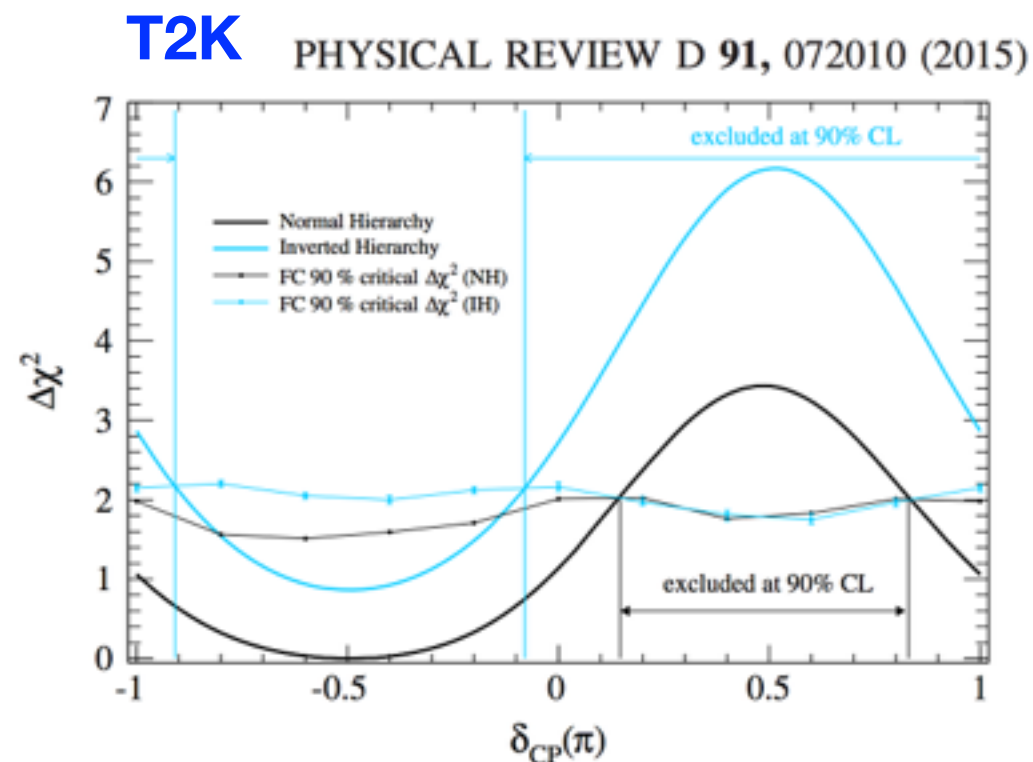
NuFact15, Rio de Janeiro

August 10, 2015



The search for CP violation!

The combinations of long baseline accelerator, reactor and atmospheric measurements are already beginning to constrain the CP phase in the 3 neutrino mixing framework



Solar neutrinos: large mixing angle MSW solution

Atmospheric neutrinos: maximal mixing

θ_{13} : Near the upper bound allowed by CHOOZ

δ_{CP} : Large CP violation?

The search for CP violation!

Measuring the CP phase in the PMNS framework isn't sufficient

Goal is observation of an asymmetry in neutrino and antineutrino oscillations

$$P_{\nu_{\mu} \rightarrow \nu_e} \neq P_{\bar{\nu}_{\mu} \rightarrow \bar{\nu}_e}$$

T2K and NOvA will both search for this asymmetry and will present recent results this week

T2K - first oscillation results with the antineutrino beam

NOvA - first neutrino oscillation results

Tuesday Plenary, 17:00

Results and Prospects from NOvA

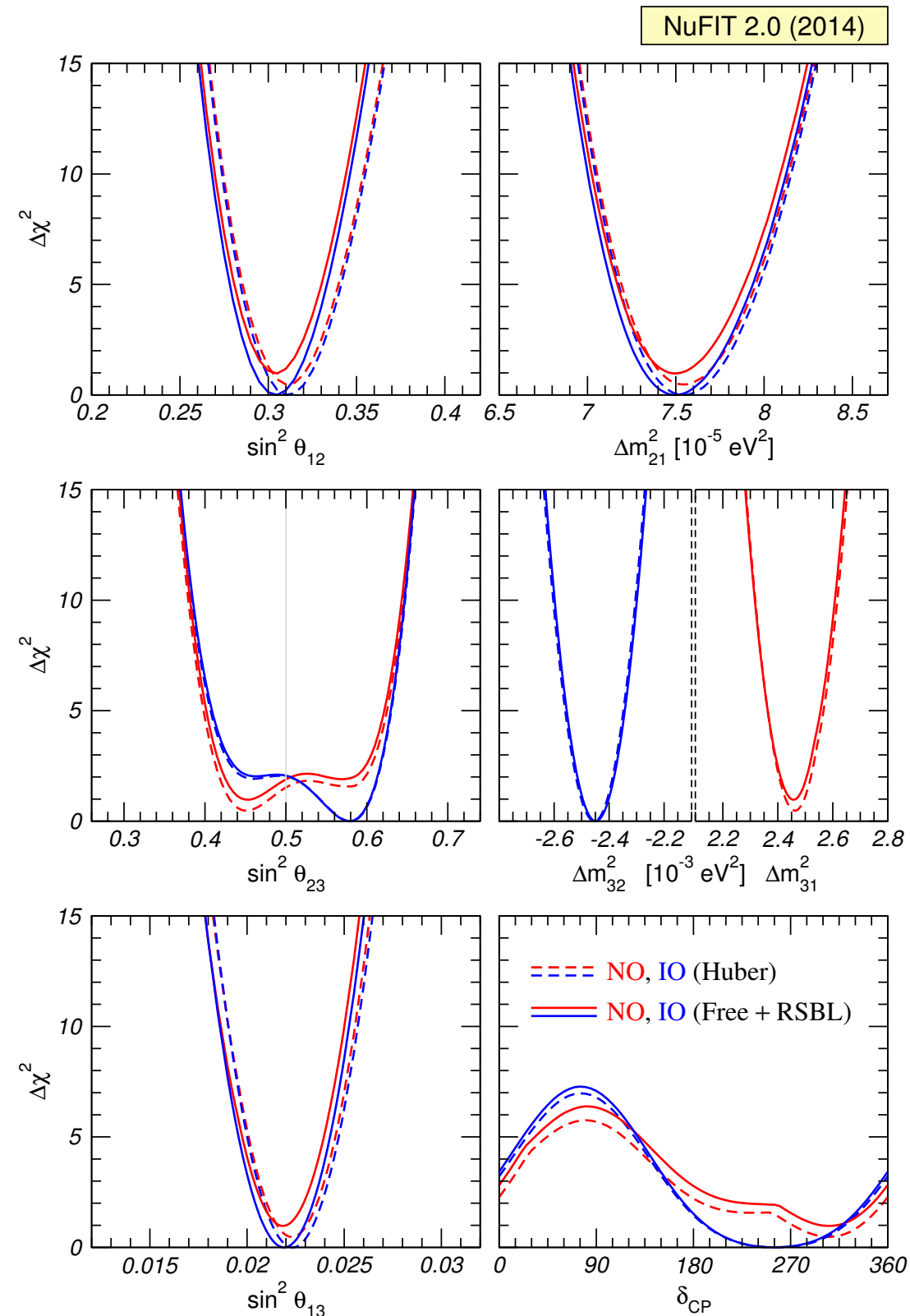
Results and Prospects from T2K

The Global Snapshot of Neutrino Mixing

The global picture is largely unchanged from last year

We are seeing a new round of results in recent weeks (T2K, NOvA, IceCube-DeepCore?)

Will we see any significant change in the global picture?



JHEP 11 (2014) 052

Questions from NuFact14 and plan for NuFact15

Flavor Models, New Physics and Experiments

- What are the new developments and predictions from flavour models on neutrino oscillation parameters? What precision do we need to achieve to probe them? Which parameters (or combinations of them) are more powerful to test them?

- Do the current bounds on new physics in the neutrino sector (NSI, non-unitarity, steriles...) allow for effects large enough to interfere with CPV searches? Which experimental setups can improve these bounds?

Monday, 14:30-16:30

Mass Model Summary

Impact of Sterile Neutrinos on LBL CP Measurements

Non-standard Interactions

DUNE Physics

Hyper-K Physics



Moved to Friday,
11:00-12:30

Atmospheric Neutrino Measurements

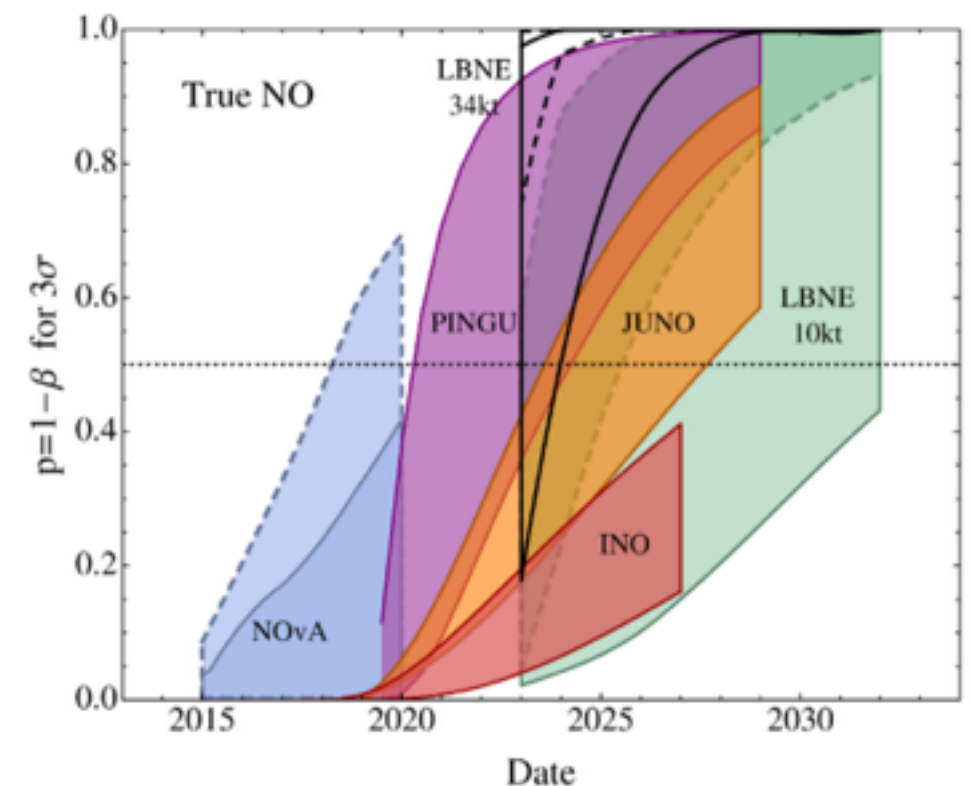
- Are atmospheric neutrino measurements competitive with next generation long baseline facilities in the determination of the mass hierarchy? And the octant of θ_{23} ? How much complementarity is there between them?

Monday Plenary, 11:30

Atmospheric Neutrino Status and Prospects

Tuesday, 14:30-16:30

Compact Formulas for Oscillations in Matter
Super-K Results and Prospects
IceCube/PINGU Results a
INO Status
CHIPS Status



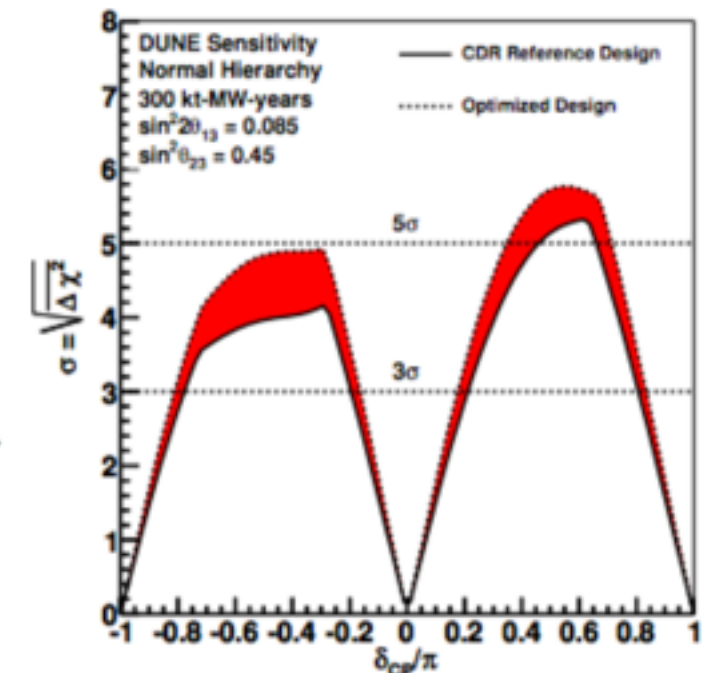
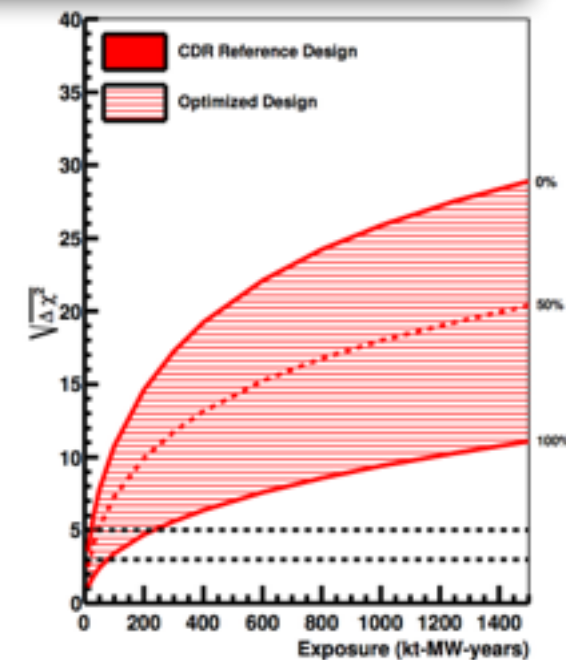
[Blennow, et al., JHEP03\(2014\)028](#)

Systematic Uncertainties

- What is the target for the systematic error budget of next generation facilities? What do we need to reach this level? How much improvement in constraining flux uncertainties can we expect from dedicated hadron production experiments?

DUNE CDR

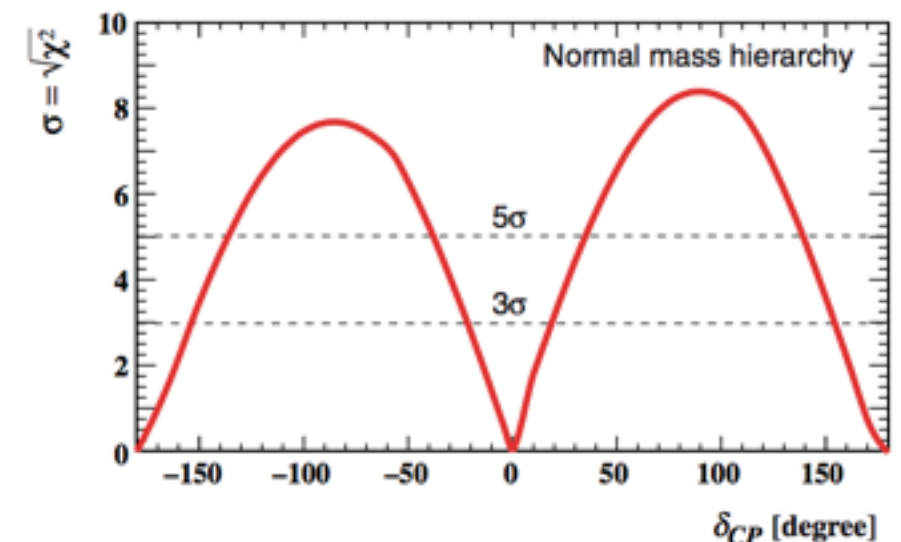
Source of Uncertainty	MINOS ν_e	T2K ν_e	DUNE ν_e	Comments
Beam Flux after N/F extrapolation	0.3%	2.9%	2%	MINOS is normalization only. DUNE normalization and shape highly correlated between ν_μ/ν_e .
Neutrino interaction modeling				
Simulation includes: hadronization cross sections nuclear models	2.7%	7.5%	~2%	Hadronization models are better constrained in the DUNE LArTPC. N/F cancellation larger in MINOS/DUNE. X-section uncertainties larger at T2K energies. Spectral analysis in DUNE provides extra constraint.
Detector effects				
Energy scale (ν_μ)	3.5%	included above	(2%)	Included in DUNE ν_μ sample uncertainty only in 3-flavor fit. MINOS dominated by hadronic scale.
Energy scale (ν_e)	2.7%	3.4% includes all FD effects	2%	Totally active LArTPC with calibration and test beam data lowers uncertainty.
Fiducial volume	2.4%	1%	1%	Larger detectors = smaller uncertainty.
Total	5.7%	8.8%	3.6%	Uncorrelated ν_e uncertainty in full DUNE 3-flavor fit = 1-2%.



Hyper-K: PTEP 2015, 053C02

Table 9. Uncertainties (in %) for the expected number of events at Hyper-K from the systematic uncertainties assumed in this study. ND: near detector.

		Flux & ND-constrained cross section	ND-independent cross section	Far detector	Total
ν mode	Appearance	3.0	1.2	0.7	3.3
	Disappearance	2.8	1.5	1.0	3.3
$\bar{\nu}$ mode	Appearance	5.6	2.0	1.7	6.2
	Disappearance	4.2	1.4	1.1	4.5



Systematic Uncertainties

Systematic error reduction: near detectors, dedicated cross section measurements, hadron production measurements.

Joint Session with WG2

Tuesday, 11:00-13:00

T2K Near Detector Experience

T2K and HK Future Near Detectors

DUNE Near Detectors

CAPTAIN and LArIAT

ANNIE

Joint Session with WG2+WG3

Thursday, 11:00-13:00

Systematic Errors for DUNE

Systematic Errors for Hyper-K

Prospects for Reducing Flux Uncertainties

Prospects for Reducing Cross Section Uncertainties

Large Δm^2 Anomalies

- What is the best strategy to fully probe the LSND anomaly?
And the reactor/gallium anomaly?

Discussion of broad range of experiments probing similar L/E
with differing energies and experimental techniques

Wednesday, 11:00-12:30

MINOS/MINOS+ Results

OPERA Results

Thursday, 14:30-16:00

Double Chooz

RENO/RENO-50

Daya Bay/JUNO

Friday, 11:00-12:30

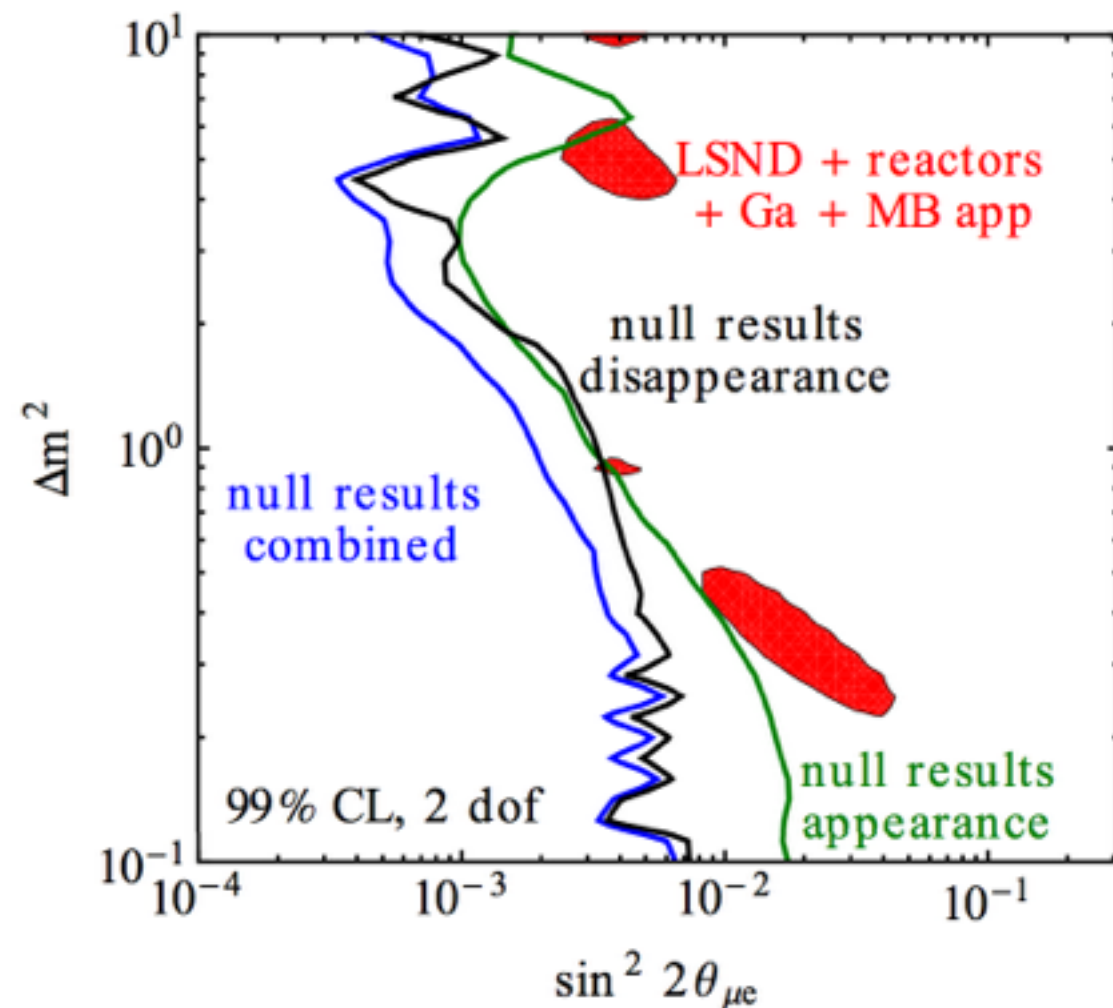
Fermilab SBL Program

Friday, 14:00-15:30

Source Experiments

Decay at Rest Experiments

SBL Reactor Experiments



J. Kopp, et al., JHEP 1305:050, 2013
arXiv:1303.3011

Synergy with Non-oscillation Measurements

- Explore the synergy between neutrino oscillations and other experiments (absolute mass searches, cosmological constraints, CLFV) to constrain new physics.

At this meeting, we will focus on the shared input of pion yield measurements relevant to muon and neutrino experiments.

WG1+WG4 Joint Session

Friday 11:00-12:30

Hadron production measurements of pion yield relevant to neutrino and muon beam lines

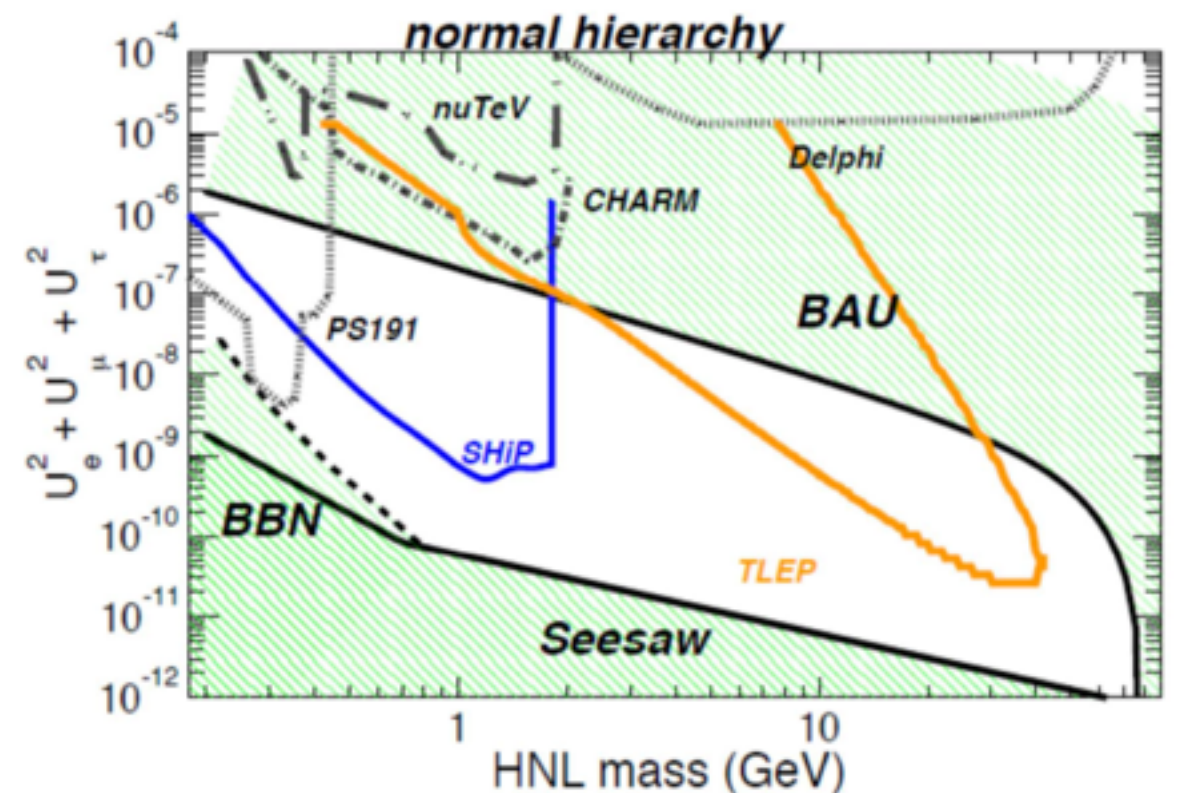
Heavy Right Handed Neutrinos

- What can we say about the new Majorana mass scale implied by neutrino masses? What are the current bounds and how much will they improve over the next decade?

Right handed sterile neutrinos at the Electroweak scale: beam dump experiments and Z factories.

Wednesday, 11:00-12:30

Heavy Neutrinos



Normal hierarchy, decay length 10-100cm, $10^{12}Z$

A. Blondel

WG1 Timetable

Monday

Tuesday

Wednesday

Thursday

Friday

11:00 - 13:00

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 11:00 T2K Near Detector Experience
- 11:24 T2K and HK future near detectors
- 11:48 DUNE near detectors
- 12:12 CAPTAIN+Lariat
- 12:36 ANNIE

11:00 - 12:30

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 11:00 MINOS/MINOS+
- 11:30 OPERA
- 12:00 Heavy Neutrinos

11:00 - 13:00

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 11:00 Impact of systematic uncertainties on DUNE
- 11:30 Impact of systematic uncertainties on Hyper-K
- 12:00 Prospects for reducing beam flux uncertainties with hadron production experiments over the next 10 years
- 12:30 Prospects for precision of neutrino cross-section measurements over the next 10 years

11:00 - 12:00

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 11:00 Fermilab SBN Program(includes MicroBooNE)
- 11:30 NA61 (focused on pion yields)

14:30 - 16:30

Room: João Alberto Lins de Barros Auditorium
Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 14:30 Mass model summary
- 14:54 The impact of sterile neutrinos on CP measurements at long baselines
- 15:18 Non-Standard Interactions: Current status and future prospects
- 15:42 DUNE Physics
- 16:06 HK Physics

14:30 - 16:30

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 14:30 Compact formulas for neutrino oscillation probabilities in matter
- 14:54 Super-K
- 15:18 IceCube/PINGU
- 15:42 INO
- 16:06 CHIPS

14:30 - 16:00

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 14:30 Theia Experiment
- 14:52 Double CHOOZ
- 15:14 RENO/RENO-50
- 15:36 Daya Bay/JUNO

14:00 - 15:30

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 14:00 Source Experiments
- 14:30 Decay at rest experiments
- 15:00 SBL Reactor Experiments

16:00 - 17:30

Location: Centro Brasileiro de Pesquisas Físicas

Contributions

- 16:00 WG1 Summary Preparation

Conclusion

LBL experiments are beginning measurements that will directly search for CP violation

We are just beginning the program of CP violation searches, mass hierarchy determination, and precision measurements that will test the PMNS mixing framework.

An exciting time for neutrino oscillation physics, so join us at the WG1 sessions!